

Zongwei Luo *Editor*

Mechanism Design for Sustainability

Techniques and Cases

 Springer

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Preface

Sustainable economy is an economy with “capacity to endure,” where bearable environment, equitable society, and viable economy are well integrated with social, culture, legal, business, financial, and environmental perspectives. To reach for this integration for sustainable development, it is essential to understand and study the mechanisms for interactions and impact from and among these perspectives. This book of mechanism design for sustainability will provide advanced analytics and decision management techniques and tools towards developing sustainable competitive advantages in the studied target context.

This edited book has 14 chapters, contributed by worldwide researchers and practitioners, of innovative concepts, theories, and models; design methods; and case studies and experience sharing in mechanism design to drive better decision makings with practical relevance to sustainable development.

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of Hong Kong, Hong Kong, China

Zongwei Luo

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Meanwhile, I would like to thank the Springer editor and other anonymous book reviewers to provide valuable suggestions to make this quality book project happen and appear to service the public.

And lastly, enjoy your reading!

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Part I
Introduction

Introduction to Mechanism Design for Sustainability

Zongwei Luo

Abstract In this chapter, an introduction to mechanism design is provided. After a brief overview of the introductory concept of mechanism design, a motivation example is presented illustrating the challenges in manufacturing transformation in China's economic structural change. The role of mechanism design to help the transformation is emphasized, followed by an introduction of mechanism design techniques and cases presented in the remaining chapters of this book.

Keywords Advanced manufacturing • Industry transformation • Mechanism design • Mechanism analysis • Structural change • Sustainability

1 Background

In philosophy, mechanism means “a theory that all natural phenomena can be explained by physical causes,” while mechanism design would include such theory design leading to explain natural phenomena or solve natural problems. In practice, mechanism design is also often related to game theory, studying game solutions. Mechanism design for sustainability invites theory as well as practice study toward solutions for sustainable development.

Sustainable development's ultimate goal is to provide “capacity to endure.” Toward that, bearable environment, equitable society, and viable economy will have to be well integrated with social, culture, legal, business, financial, and environmental perspectives. To reach for this integration for sustainable development,

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it is essential to understand and study the mechanisms for interactions among and impact from these perspectives. Sustainability mechanism solutions will then be followed. The mechanism design for sustainability would provide advanced analytics and decision management techniques and tools toward theory and solutions development with sustainable competitive advantages.

The world now is at the point to pursue a sustainable development roadmap that would eventually decouple economic growth from greenhouse gas and other polluting emissions, through social, technological, and business innovations. China, with the largest world manufacturing capacity, is the country with the largest carbon emission in the world. China's manufacturers import resources worldwide and then export major parts of its produced products. China's portion of value add is in fact very small but with a large portion of pollution left. Apparently, China's economy does not hold the capacity to endure if China continues this pattern of economy development. Its current economy structure has to change to facilitate development of technology-rich, high value-add, and service-oriented manufacturing industries. Thus, China's manufacturing industry presents an excellent case of sustainability study needs, which will be discussed in the next few sections.

The rest of this chapter will be divided into two parts. The first part will be devoted to a study of the role of manufacturing industry to sustain China's economy growth as an illustration of the need for mechanism design for sustainability. The change expectation is analyzed. Manufacturing's role in promoting sustainability is discussed. Future trend of manufacturing development is given. And development considerations for smart manufacturing toward sustainability are also analyzed. Beyond manufacturing, as an illustration for mechanism design for sustainability, the second part of this chapter includes a brief overview of the selected book chapters introducing a rather comprehensive view on mechanism design for sustainability techniques, analysis, and case studies.

2 Change Expected

Today the world is at a point facing worldwide economic structural adjustment, change, and reorganization, presenting historical opportunities to China and of course other countries as well. China's national export-oriented economy urgently needs transformation, with urgent need to adjust industrial structures and to enhance domestic demand to sustain China's economic development. Advanced manufacturing, strategic emerging industries, and modern services represent the direction of the scientific, technological, and industrial change, which China has started vigorously to pursue and develop in order to expand and create market demand. Deep integration and synergy among these industries will support China's technological and industrial change, helping China to occupy a favorable position in this competitive world with ongoing global restructuring and international industrial transfer and the international industry adjustment.

3 Manufacturing's Role

Advanced manufacturing's role as the backbone of the country has been re-recognized and has aroused wide attention of major developed countries. These countries have already started a series of advanced manufacturing technology research programs. And without exception, digital manufacturing technology is one of the important components in the study. Europe and the United States proposed "reindustrialization" in recent years and wish to return to the real economy to seize the commanding control of global industrial technology and to further capitalize on the high-end manufacturing. In the USA, President Barack Obama has announced infrastructure and technology policy and steps to restore the center of manufacturing in the US economy. The American Association of Manufacturers has also released several goals for the revitalization of US manufacturing, including (1) the United States to become the world's most superior manufacturing center and a place to attract foreign direct investment, (2) US manufacturers have to meet the economic needs of labor in the twenty-first century, and (3) the US manufacturers become the world's leading innovators. They believe that a world-class manufacturing requires world-class talents for the US's manufacturing sector; if you want to maintain its dominant position in the world, you must have the best domestic and foreign high-skilled personnel in order to maintain a dominant position. To become the world's leading innovators, the United States must maintain research and development activities, with efforts of promotion and protection of intellectual property rights.

In the face of fierce international competition in the twenty-first century, the Chinese government has planned accordingly and launched a series of major and key scientific research and development projects, carrying out special studies in the frontier of advanced manufacturing technology and equipment. In late April of this year, the Ministry of Science and Technology, in combination with other ministries, has issued a "12/5" Manufacturing Information Technology Project Planning, outlining manufacturing information technology projects over the next 5 years for the development of manufacturing services and intelligent manufacturing. In recent years, the National Hi-Tech Research and Development Program (863 Program) in 2008 and 2006 has called for "advanced manufacturing technology major projects in the field of radio frequency identification (RFID) technology and applications" by the development and application of RFID technology to promote transformation and upgrading of China's advanced manufacturing industry.

4 Manufacturing Development Trends

Development of the manufacturing industry so far has involved with multidisciplinary applications, and manufacturing technologies have more and more adopted the latest achievement in materials, mechanics, physics, chemistry, and computer simulation technology, network technology, control technology, nanotechnology, biotechnology, and sensor technology. Currently, with booming economy, China

has respected more science- and technology-led economic development. It is generally believed that the Internet/Internet of Things and next generation of information technology will lead to industrial change toward the advent of an era of wisdom and knowledge, promoting the manufacturing industry to shift from the traditional manufacturing toward industrial chain-based manufacturing. The trend and requirements of digital manufacturing, service manufacturing, and intelligent manufacturing will become more apparent and prominent.

4.1 Digital Manufacturing

Digital manufacturing is a strategic choice for manufacturing innovation, including digital design, digital management, digital production, digital manufacturing equipment, and digital enterprise. Further integration of information technology into digital manufacturing will promote and extend digital manufacturing from traditional manufacturing to both ends of the industry chain, evolving toward industrial chain-based digital manufacturing. This industrial chain-based manufacturing would help effective coordination of worldwide design and manufacturing resources, improve the capacity of complex product development and product lifecycle optimization, shorten the development cycle, and reduce development cost, which can greatly enhance the capability of independent innovation and market competitiveness of China's manufacturing industry.

4.2 Service Manufacturing

Development of service manufacturing would be in the direction toward industry chain-based manufacturing providing capacity of customer-oriented, on-demand products and services, improving the consistency between the enterprise and customer goals, and achieving win-win situations. Service manufacturing would stay close to the market and demand, enhance the understanding of the needs and ability to create harmonious win-win development capabilities on the basis of collaborative innovation with customers, and form capability to grasp control of the industrial chain and achieve competitive advantages.

4.3 Intelligent Manufacturing

Intelligent manufacturing evolved from the traditional artificial intelligence, usually demonstrated as intelligent machines to show the performance of flexible and intelligent manufacturing systems in the manufacturing unit and flexible and intelligent network-based integration. Volatility of consumer demand and uncertainty of economic

activity continue to grow. Diversified varieties and small batch manufacturing demand will become a normal pattern. Flexible and intelligent manufacturing to realize personalized service manufacturing is a reasonable choice, the development trend of future manufacturing.

5 Smart Manufacturing for Sustainability

All of these trends will lead to smart manufacturing. In recent years, China maintains a booming outlook of rapid economic development. In 2010, its national manufacturing sector has surpassed the USA as the top 1 manufacturing country in the world. At the same time, China is eager to move toward high-end manufacturing power, having set the research theme of smart manufacturing at high priority.

At present, the world is moving toward an era of wisdom, on the bases of digital, intelligent, and service development. Smart manufacturing, established on the basis of digital, service, and intelligent manufacturing, is an effective way to transform traditional manufacturing to achieve high-precision, high-efficiency, and high-reliability manufacturing and enhance the capacity for the transformation and upgrading. In recent years, the USA continues to introduce intelligence into their economic activities. It liberated more and more Americans into more intelligent and higher value-added industries. This intellectual revolution has begun to threaten Chinese manufacturing industry, forcing China to transform from industrial age competition toward seizing the controlling methods and tools to gain global competitive advantages in the era of wisdom and knowledge.

In China, manufacturing is the cornerstone of national economy. However, it seats in the low end of the industrial chain. Its potential pulling power for improving domestic demand on the national economy is not adequately reflected. Big but not strong characterizes China's current manufacturing, with urgent need to improve its competitiveness in the world. Current market situation still demands the implementation for upgrading, transformation, and relocation policies. In the process of this industrial restructuring, smart manufacturing development presents a viable way to leverage this scientific and technological progress to interface and meet the high-end development needs of manufacturing industry.

6 Further Considerations

China's President Hu Jintao has already voiced China's determination to develop its economy in a sustainable way with smart manufacturing development set as one of the strategic emerging industries. However, smart manufacturing development will have to face and address numerous challenges in order to lead to manufacturing sustainability for China to facilitate development of technology-rich, high value-add, and service-oriented manufacturing industries.

Smart manufacturing is by its nature multidisciplinary across the knowledge domains of business, management, and technology, covering a wide spectrum of activities in the economic value chain. To exert a major impact, breakthroughs are necessary in the relevant theories, engineering, and technological aspects in facilitating mechanism design with relevant policy, business, and technology innovation and practice adoption for manufacturing excellence for sustaining China's economy growth. Specifically, the following breakthroughs are needed in respect of the challenges for a major impact: (1) breakthroughs in policy support via forming sustainable ecosystem for world situation adaptation and mitigation; (2) breakthroughs in efficient collaborative methods and operational support in and across the industries and innovative capabilities and financing models to develop technology-rich, high value-add, and service-oriented manufacturing industry; and (3) breakthroughs in enabling high-end product development and manufacturing capacity. All of these demand a careful mechanism design for sustainability.

7 Mechanism Design for Sustainability

China's manufacturing industry exerts an excellent case for illustrating the need of mechanism design for sustainability. In view of this need, state-of-the-art progress in mechanism design for sustainability techniques and case studies is solicited to provide a good reference in the area.

And the rest of the book is organized into three parts, Part II, III, and IV, all contributed by researchers and practitioners worldwide. Part II includes chapters related to mechanism design techniques for sustainability. Part III includes chapters related to sustainability mechanism analysis. Part IV includes sustainability cases. Each of these chapters will introduce mechanism design for sustainability techniques, analysis, or cases. All of those chapters make up an excellent set of reference materials covering a comprehensive range of sustainability issues with academic merits as well as practical relevance. The abstract of each chapter is briefly introduced as follows:

Part	Chapter	Title, authors, and abstract
II	2	Multi-criteria Decision Making: A Mechanism Design Technique for Sustainability
–	–	Fabio De Felice and Antonella Petrillo
–	–	This chapter aims to present an approach based on the analytic hierarchy process (AHP) to manage collaborative relationships under an integrated approach in order to investigate and promote mechanism design for sustainability. With this approach, enterprises will obtain significant information for the decision-making process regarding sustainable performance elements that have the greatest impact on their competitiveness and therefore should be prioritized
–	3	Mechanism Design for Allocation of Carbon Emission Reduction Units: A Study of Global Companies with Strategic Divisions and Partners

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Part	Chapter	Title, authors, and abstract
–	–	Deepak Bagchi, L. Udaya Lakshmi, Y. Narahari, Shantanu Biswas, P. Suresh, S. V. Subrahmanya, and N. Viswanadham
–	–	The problem addressed in this work is concerned with an important challenge faced by any green aware global company to keep its emissions within a prescribed cap. The specific problem is to allocate carbon reductions to its different divisions and supply chain partners in achieving a required target of reductions in its carbon reduction program. Mechanism design theory has shown that it is not possible to achieve the three identified properties simultaneously. Two protocols are proposed and their performance is evaluated using a stylized, representative case study
–	4	Six Sigma Methodology for the Environment Sustainable Development
–	–	Seifedine Kadry
–	–	The Six Sigma methodology, as it has evolved over the last two decades, provides a proven framework for problem-solving and organizational leadership and enables leaders and practitioners to employ new ways of understanding and solving their sustainability problems. While business leaders now understand the importance of environmental sustainability to both profitability and customer satisfaction, few are able to translate good intentions into concrete, measurable improvement programs. Increasingly, these leaders are looking to their corps (Six Sigma experts) of Six Sigma “Master Black Belts,” “Black Belts,” and “Green Belts” to lead and implement innovative programs that simultaneously reduce carbon emissions and provide large cost savings. In my experience, and that of many others, Six Sigma processes show a proven approach for businesses and organizations to improve their performance, and that sustainability programs are in need of this operational approach and discipline. Six Sigma rigors will help a business leader to design a sustainable program for both short- and long-term value creations. The aim of this chapter is to show the importance of applying Six Sigma methodologies to multidisciplinary sustainability-related projects and how to implement it
III	5	Soft TQM for Sustainability: An Empirical Study on Indian Cement Industry and Its Impact on Organizational Performance
–	–	Tripti Singh and Rameshwar Dubey
–	–	As we embark into a new era which has witnessed global slowdown and intense competition to survive, it is quite appropriate to revisit the role of total quality management (TQM) in enabling and supporting firm to sustain superior performance. This chapter is concerned with soft dimensions of TQM which not only help it in successful implementation but also provide sustainable competitive advantage. Sustainability can perhaps be correlated with the principle of excellence which is now gaining wider acceptance in the business community (Zairi 2005). The present research proposes a soft TQM framework and empirically tested the impact of soft dimensions of TQM on its performance in context to Indian cement industry to understand how soft TQM can help Indian cement industry to sustain competitive advantage in long term. The chapter concludes with a statement that soft dimensions of TQM are critical for sustainability which enables cement firms to achieve superior performance
–	6	An Energy Optimization Framework for Sustainability Analysis: Inclusion of Behavioral Parameters as a Virtual Technology in Energy Optimization Models

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Part	Chapter	Title, authors, and abstract
–	–	Roman Kanala, Nathalie Turin, and Emmanuel Fragnière
–	–	This chapter introduces an innovative approach that combines the deductive method used to construct normative energy-economy models and the inductive method of social sciences. Consumer behavior is described via technological attributes and used in virtual process technologies in an energy optimization framework. The main finding is that it is possible to evaluate consumer information and behavior together with technological progress and integrate them on the same modeling platform. The approach eliminates the systematic error on the demand side where the efficiency of demand-side management measures is over optimistic, which may lead to inaccurate decisions and poor policies. Thus, this method paves the way to a new stream in energy modeling
–	7	Supply Chain Evolution for Sustainability Focused Firms: Content Analysis Toward Socially and Environmentally Friendliness
–	–	Ozan Özcan and Kingsley Anthony Reeves Jr.
–	–	The objective of this research was to understand how the organizational structure of sustainability-focused companies changes over time as the companies become more environmentally, economically, and socially sustainable. We applied trend analysis to the sustainability scores and vertical integration level of the companies. The study results demonstrated an increasing trend in both vertical integration and sustainability development of industrials industry companies over a 15-year period. Furthermore, the companies became more vertically integrated as their environmental, economical, and social sustainability increased
–	8	Community Participation Mechanism: A Study of Youth Voices in Conservations' GreenLeaf Marketplace
–	–	Leonard Sonnenschein
–	–	The Youth Voices in Conservation Program has researched youth action toward conservation and sustainability from the classroom, the field site, and within nongovernmental and governmental organizational situations for the past few years. This research found that by developing a residual funding based upon carbon credit offsets created by these localized actions, there is a possibility of conditional cash transfer based upon these “good actions.” The results of this research indicate that the Youth Voices in Conservation’s GreenLeaf Program may be able to address localized sustainability issues as well as methodology for decreasing carbon footprints and increasing financial sustainability within each community, and consequently the environmental effects from the wide-scale adoption of these plans may be expected
–	9	The “Ecological” Stock: “A Financial Market Instrument for Global Scale Climate Change Mitigation”
–	–	Vicente Rappaccioli Navas
–	–	This financial market instrument first addresses the issue of “global risk”: the combined world economic, political, and social risk that is rapidly resulting from the unparalleled planetary environmental degradation and climate change. It provides evidence that “global risk” can be reduced with investments in forest preservation, reforestation, and renewable energy. Furthermore, it shows that in order to achieve the urgently needed global scale climate change mitigation and neutralization, new massive capital investments can be stimulated and, thereby, shifted, through the profit motive utilizing financial product innovations in the free market system with the active participation of the private sector. The “ecological” stock is a certifiable and tradable innovative instrument that incorporates features of a corporate stock, a commodity, a derivative, and perpetuity

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Part	Chapter	Title, authors, and abstract
IV	10	The Sustainable Development of Trasimeno Lake
–	–	Adriano Ciani, Luigi Porcellati Pazzaglia, Lucia Rocchi, Francesco Velatta, and Mauro Natali
–	–	The defense and the development of Lake Trasimeno are a complex and articulated task. Nevertheless, the preservation of a dynamic equilibrium and a management increasingly inspired to the principles of sustainability make up study case of relevant interest and of concern for experts and ordinary citizens who care about the future of the entire world and its essential diversity
–	11	Sustainable Farm: A Case Study of a Small Farm from Pali, India
–	–	Dheeraj Singh, M. K. Choudhary, M. L. Meena, S. Kachhawaha, and P. K. Tomar
–	–	Along with agriculture, the farmer is having livestock which yields milk, and the dung is converted into valuable vermicompost. Thus, this model of multifunctional small farm which integrates crops, horticulture, livestock, and natural vegetation is key to sustainable development in countries dominated by small farms
–	12	Sustainable City: A Case Study of Stormwater Management in Economically Developed Urban Catchments
–	–	Deepshikha Sharma and Arun Kansal
–	–	The present study comprises of qualitatively evaluating the role of sustainable urban drainage systems in stormwater management of dense urban cities. The following chapter talks about an approach to manage rainfall runoff arising due to urbanization which is a direct impact of economic growth of a city
–	13	Sustainable Software: A Study of Software Product Sustainable Development
–	–	Malgorzata Pankowska
–	–	The intention of this chapter is to propose a distinct approach to software development sustainability as well as a different understanding of sustainability in the context of software development. The chapter covers survey of good practices and software development methods as important for sustainable development of software products. Particularly, the author focuses on agile methods and product line engineering as approaches supporting the sustainable development of software product. The analyzed practices and methods are suggested to be implemented for the software company sustainability. The implementation results in saving human efforts as well as energy and computer power
–	14	Sustainability Policy: A Case Study of the Limits to Biofuel Sustainability
–	–	Henrique Pacini, Andrei Cechin, and Semida Silveira
–	–	This chapter explores biofuel sustainability policies, their economic rationale, and specially their limits, as seen from the basic strategies of dematerialization, detoxification, and transmaterialization. The chapter then frames where biofuels' sustainability policies have margin for action, exemplified by the case of the European scheme proposed in 2009. By understanding the economic rationale and guiding principles behind efforts to improve biofuels sustainability, the chapter can contribute to better understand the actual scope and limitations of policy efforts currently aiming to promote responsible biofuel usage. The study concludes by proposing that transparency and dialogue are including parties directly and indirectly affected by biofuel strategies as the only way to legitimize the sharing of risks in this emerging international market

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Part II
Mechanism Design Techniques
for Sustainability

Multi-criteria Decision-Making: A Mechanism Design Technique for Sustainability

Fabio De Felice and Antonella Petrillo

Abstract Sustainable development has become a key concept in environmental and economic policy analysis. From this point of view, it is desirable to integrate culture, legal, business, and financial prospective and increase collaboration among enterprises in order to improve sustainable competitiveness. Enterprises that are collaborating need to define and use performance measurement/management frameworks composed of performance elements (objectives, performance indicators, etc.) that facilitate the management of their activity, as well as monitor their strategy and processes. There are several factors that need to be managed properly in order to support collaborative success. So this chapter aims to present an approach based on the analytic hierarchy process (AHP) to manage collaborative relationships under an integrated approach in order to investigate and promote mechanism design for sustainability. With this approach, enterprises will obtain significant information for the decision-making process regarding sustainable performance elements that have the greatest impact on their competitiveness and therefore should be prioritized.

Keywords Decision support • AHP technique • Mechanism design • Sustainability • MCDM

1 Introduction

Sustainable development was most popularly developed by the World Commission on Environment and Development (WCED) in *Our Common Future* in 1987 (WCED 1987). A direct quotation from WCE Dreads: “*Sustainable development is development that meets the needs of the present without compromising the ability of future*

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generations to meet their own needs.” Since “sustainable development” was adopted as an overarching goal of economic and social development by Agenda 21, many countries, governments, and even private enterprises, it has generated a huge body of research (Hopwood et al. 2005; Pati et al. 2008).

A large body of literature has evolved around the concept of sustainable development; many contributions are in a general and descriptive manner and lack of theoretical and operational analysis (Gnoni et al. 2011). One possible reason may be that elaborating on the concept requires complicated and interdisciplinary approach (Van den Bergh 1996; Paucar-Caceres 2010). Sachs and Reid (2006) highlighted the importance of interdisciplinary strategy in sustainable development.

To reach sustainable development, it is essential to understand and study the mechanisms for interactions and impact among different perspectives. From this point of view, mechanism design for sustainability is a useful approach that intends to provide advanced analytics and decision management techniques and tools toward developing sustainable competitive.

Mechanism design considers how to implement good system wide solutions to problems that involve multiple self-interested agents, each with private information about their preferences. In recent years, mechanism design has found many important applications, for example, in electronic market design, in distributed scheduling problems, and in combinatorial resource allocation problems.

Of course, it is necessary to apply a proper techniques to develop mechanism design for sustainable competitive. What we need is a *systematic and comprehensive approach* to decision-making.

In fact, such as our lives are the sum of our decisions, so in similar way it is also in business or in research spheres. Often, *when* we decide is as important as what we decide. Deciding too quickly can be hazardous; delaying too long can mean missed opportunities. In the end, it is crucial that we make up our mind.

This need calls for a new logic, a new way to cope with the myriad factors that affect the achievement of goals and the consistency of the judgments we use to draw valid conclusions.

From this point of view, decision-making and in particular MCDM – multi-criteria decision-making – is a field that seems very fit to choose the best of a discrete set of alternatives and to apply mechanism design for sustainability. Unlike the usual methods of optimization that assume the availability of measurements, measurements in MCDM are assumed to be derived or interpreted subjectively as indicators of preference and of the strength of preference.

Decision-making is fundamental to furthering our goal of survival and ensuring the quality of our life. *To be a person is to be a decision-maker.* Life is worth little if we are not free to make our own choices.

The analytic hierarchy process (AHP) (developed by Prof. Thomas L. Saaty in the 1970s), the MCDM technique, described in this chapter and now widely used in decision-making – is a theory that depends on the values and judgments of individuals and groups.

Our primary purpose in writing this chapter is to introduce the reader to a new way of making decisions in a complex environment and in particular in *mechanism design*

for sustainability. The method is based on the user's experience and judgments supported by explanations that ensure a sense of realism and a broad perspective.

The unique features of the chapter are the simplicity of the approach (it involves only simple arithmetic). This approach should not be regarded simply as a technique; it is a general method for coping with unstructured problems.

The process contributes to solving complex problems by structuring a hierarchy of criteria, stakeholders, and outcomes and by eliciting judgments to develop priorities. It also leads to prediction of likely outcomes according to these judgments. The outcome can be used to rank alternatives, allocate resources, conduct benefit/cost comparisons, exercise control in the system by evaluating the sensitivity of the outcome to changes in judgment, and carry out planning of projected and desired futures. A useful by-product is the measurement of how well the leader understands the relations among factors. Although people generally are not consistent, the main concern here is the strength of their inconsistency.

Our ability to choose by reflecting on the complexities of a decision and how that decision may affect the future is largely what separates us from other forms of life. The choices we make depend mostly on what purpose we want to achieve. Our purpose arises out of our vision of what we think is ultimately of greatest importance to us. We then take actions that we believe will allow us to carry out our purpose and fulfill our vision. There are cases, however, when one's freedom of choice is constrained. Many decisions involve groups of people who must reconcile their different criteria and goals. In the end, decision-making is closely related to conflict resolution. Thus, the benefits we derive from the decisions we make are largely determined by how well we can deal with differences in opinion and how well we can foresee risks and opportunities and plan for the future.

The AHP can help bring together a diverse group of people with different perspectives to make the complex decisions required in our time. They offer a structured framework for discussion and debate, a way to include the important intangibles of every major decision together with the tangibles, and a way to resolve conflicts over turf and achieve buy-in to implement the decision at the end of the day (Saaty et al. 2003).

The AHP has been applied to a large variety of decisions: marketing, medical, political, social, and forecasting and prediction and many others. Its accuracy is impressive in predicting economic trends, winners in sports, and other events for which the outcome later became known.

2 The Decision-Making Process and Multi-criteria Decision-Making Methods (MCDM)

Decision-making is the study of identifying and choosing alternatives based on the values and preferences of the decision-maker. Making a decision implies that there are alternative choices to be considered, and in such a case, we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on.

MCDM techniques have become increasingly popular in recent years and are widely used in energy planning (e.g. Cavallaro and Ciraolo 2005; Gamboa and Munda 2007; Stagl 2006). Major advantages of the MCDM methodology over other decision-support methods are that the methodology acknowledges that decision-making is a complex process and helps to provide a rational basis for the structuring of decision-making. MCDM helps to overcome some of these issues to a greater extent than other decision-support tools, such as cost–benefit analysis. The methodology is capable of considering a number of different objectives, which can be weighted to reflect the hierarchy of objectives. The methodology often involves widespread stakeholder participation; this can act to improve the accountability and transparency of decisions reached and to provide greater levels of ownership over the decision-making process and its outcomes. For these reasons, diverse applications of MCDM are often used in government and public sector planning where the accountability of decisions to the public is vital.

MCDM are often used in government and public sector planning where the accountability of decisions to the public is vital. This involvement of stakeholders is one of the main drivers behind the development and use of MCDM. This method facilitates the process of decision-making by making clear the assumptions of the various stakeholders by providing a structured process with an audit trail supporting learning and evaluation. This allows for transparency to stakeholders and can be easily followed by local residents. However, the transparency surrounding the methodology does not necessarily lead to social acceptance of the decision outcome. Social acceptance is based on complex processes involving a variety of cognitive and emotive elements, and different social actors will have different and possibly contrasting viewpoints; in cases where such conflicts arise, full social acceptance may be impossible to achieve. Although social acceptance may be difficult to achieve, the transparency surrounding the method does allow stakeholders to see the processes that were undertaken in the decision-making exercise, even if they do not fully agree with the final decision outcome.

These strengths of the MCDM have led to its rapid development over recent years, and a number of different methods have been developed including ELECTRE III (Roy 1978), analytical hierarchy process (Saaty 1980), PROMETHEE II (Brans et al. 1985), NAIADE (Munda 1995), and MACBETH (Bana e Costa and Vansnick 1997, 1999). MCDM can generally be split into two classes: multiple objective decision-making, where the alternatives are not predetermined but a set of objective functions is optimized until the most efficient solution is found, and multiple attribute decision-making, where alternatives are determined and the decision-maker indicates his preference for each objective, until an efficient solution is found (Haung et al. 1995).

Pohekar and Ramachandran investigated several methods based on weighted averages, priority setting, outranking, fuzzy principles, and their combinations which employed for energy planning decisions. They presented a review of more than 90 published papers to analyze the applicability of the methods. It was observed that AHP is the most popular technique followed by outranking techniques PROMETHEE and the elimination and choice translating reality (ELECTRE) (Pohekar and Ramachandran 2004).

2.1 Scientific Approach for Resolution of Problems

It is very important to make distinction between the cases whether we have a single or multiple criteria.

The decision can be made implicitly by determining the alternative with the best value of the single criterion or aggregate measure.

Consider a multi-attribute decision-making problem with m criteria and n alternatives. Let C_1, \dots, C_m and A_1, \dots, A_n denote the criteria and alternatives, respectively. A standard feature of multi-attribute decision-making methodology is the *decision table* as shown below. In the table, each row belongs to a criterion, and each column describes the performance of an alternative. The score a_{ij} describes the performance of alternative A_j against criterion C_i . For the sake of simplicity, we assume that a higher score value means a better performance since any goal of minimization can be easily transformed into a goal of maximization. As shown in decision table, weights w_1, \dots, w_m are assigned to the criteria. Weight w_i reflects the relative importance of criteria C_i to the decision and is assumed to be positive. The weights of the criteria are usually determined on subjective basis. They represent the opinion of a single decision-maker or synthesize the opinions of a group of experts using a group decision technique, as well.

The values x_1, \dots, x_n associated with the alternatives in the decision table are the final ranking values of the alternatives. Usually, higher ranking value means a better performance of the alternative, so the alternative with the highest ranking value is the best of the alternatives (Table 1).

Multi-attribute decision-making techniques can partially or completely rank the alternatives: a single most preferred alternative can be identified, or a short list of a limited number of alternatives can be selected for subsequent detailed appraisal.

Besides some monetary-based and elementary methods, the two main families in the multi-attribute decision-making methods are those based on the multi-attribute utility theory (MAUT) and outranking methods.

The family of MAUT methods consists of aggregating the different criteria into a function, which has to be maximized. Thereby the mathematical conditions of aggregations are examined. This theory allows complete compensation between criteria, that is, the gain on one criterion can compensate the lost on another (Keeney and Raiffa 1976). The concept of outranking was proposed by Roy (1968). The basic idea is as follows. Alternative A_i outranks A_j if on a great part of the criteria A_i performs at least as good as A_j (concordance condition), while its worse performance is still acceptable on the other criteria (non-discordance condition). After having determined for each pair of alternatives whether one alternative outranks another, these pairwise outranking assessments can be combined into a partial or complete ranking. Contrary to the MAUT methods, where the alternative with the best value of the aggregated function can be obtained and considered as the best one, a partial ranking of an outranking method may not render the best alternative directly. A subset of alternatives can be determined such that any alternative not in